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Research article

Hydration Status and Fluid Balance of Elite European Youth Soccer Players during Consecutive Training Sessions

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Abstract

The objective of the study was to investigate the hydration status and fluid balance of elite European youth soccer players during three consecutive training sessions. Fourteen males (age 16.9 ± 0.8 years, height 1.79 ± 0.06 m, body mass (BM) 70.6 ± 5.0 kg) had their hydration status assessed from first morning urine samples (baseline) and pre- and post-training using urine specific gravity (USG) measures, and their fluid balance calculated from pre- to post-training BM change, corrected for fluid intake and urine output. Most participants were hypohydrated upon waking (USG >1.020 ; 77% on days 1 and 3, and 62% on day 2). There was no significant difference between first morning and pre-training USG ($p = 0.11$) and no influence of training session ($p = 0.34$) or time (pre- vs. post-training; $p = 0.16$) on USG. Significant BM loss occurred in sessions 1-3 (0.69 ± 0.22 , 0.42 ± 0.25 , and 0.38 ± 0.30 kg respectively, $p < 0.05$). Mean fluid intake in sessions 1-3 was 425 ± 185 , 355 ± 161 , and 247 ± 157 ml, respectively ($p < 0.05$). Participants replaced on average $71.3 \pm 64.1\%$ (range 0-363.6%) of fluid losses across the three sessions. Body mass loss, fluid intake, and USG measures showed large inter-individual variation. Elite young European soccer players likely wake and present for training hypohydrated, when a USG threshold of 1.020 is applied. When training in a cool environment with *ad libitum* access to fluid, replacing ~71% of sweat losses results in minimal hypohydration ($<1\%$ BM). Consumption of fluid *ad libitum* throughout training appears to prevent excessive ($\geq 2\%$ BM) dehydration, as advised by current fluid intake guidelines. Current fluid intake guidelines appear applicable for elite European youth soccer players training in a cool environment.

Key words: Specific gravity; exercise; urine; adolescent.

Introduction

Soccer is a variable intensity endurance sport with an overall intensity of 70-80% $\text{VO}_{2\text{max}}$, dependent in part on playing position and performance level (Bangsbo et al., 2006). The intensity of soccer is sufficient to elevate core body temperature and initiate a sweating response, which may generate a net loss of body water unless this water is replaced via fluid intake (Edwards and Noakes, 2009).

Several studies have investigated fluid balance in soccer players during laboratory exercise protocols (Drust et al., 2000; Maxwell et al., 2009; Nicholas et al., 1995). However, the laboratory environment may not adequately mimic conditions faced by soccer players undertaking habitual training and competition in the field, such as variability in environmental temperature, humidity, and wind strength, and differences in the intensity of training

and competition. Existing field-based research in adult soccer players reports large variations in sweat rate (SR) and sweat losses between players (Shirreffs et al., 2006), and incidences of players beginning training in a hypohydrated state (Maughan et al., 2005).

Existing field-based research into fluid balance and hydration status in soccer players has largely focused on measuring adult athletes on a single day, and data on the fluid balance, sweat loss, and hydration status of young soccer players during training and competition is sparse (Silva et al., 2011). Factors such as chronological age, biological maturation, morphology, and anthropometry can influence cardiovascular and thermoregulatory responses to exercise (Havenith, 2001; Rowland, 2008). Therefore, it is important to investigate fluid balance, hydration status, and associated fluid intake practices in young soccer players (Silva et al., 2011). Recently, Silva et al. (2011) showed that elite Brazilian soccer players (17.2 ± 0.5 years) began each of three consecutive training sessions (mean temperature 30.1°C , relative humidity 59.6%) mildly hypohydrated and did not voluntarily ingest sufficient fluid during training to offset sweat losses. Comparable findings have been reported during a competitive soccer match with similar participants (elite Brazilian players, 17.0 ± 0.6 years) and environmental conditions (31.0°C , 48.0% relative humidity; Da Silva et al., 2012). These findings indicate that young soccer players may be at risk of developing hypohydration during soccer training and competition.

In the studies of Silva et al. (2011) and Da Silva et al. (2012), urine specific gravity (USG) was used to quantify hydration status pre- and post-training/competition, but neither study measured USG from first-morning urine samples. Hydration status can be estimated by analysing the first urine excretion of the day as urine concentration in this sample is sufficiently sensitive to detect deviations in fluid balance (Sawka et al., 2007; Shirreffs and Maughan, 1998). Furthermore, the first morning urine sample is advantageous over urine samples taken at other times as it is not affected by acute fluid ingestion, which can mask true hydration status (Oppliger and Bartok, 2002). For these reasons, guidelines emphasise the need to use first morning urine samples to allow discrimination between euhydration and dehydration (Sawka et al., 2007). Additionally, neither Silva et al. (2011) nor Da Silva et al. (2012) quantified the intensity of the training sessions/competition, making it difficult to interpret the hydration data within the context of the exercise demands.

The data from Silva et al. (2011) indicates that

young soccer players exhibit voluntary hypohydration during consecutive training sessions in a hot and humid environment. However, the data is not generalisable beyond the sample used and the environmental conditions in which the study was conducted. Data for elite young European soccer players undertaking typical training in a temperate environment is not available; therefore, further study into hydration status and fluid balance in this sample is warranted. The aim of this study was to assess first morning, pre- and post-training hydration status and fluid balance of elite European youth soccer players during three consecutive days of soccer training.

Methods

Participants

Fourteen male soccer players volunteered for the study, all of whom were members of the same elite youth academy team (mean time at the academy 3.9 ± 2.9 years). The characteristics of the participants were: age 16.9 ± 0.8 years, height 1.79 ± 0.06 m, body mass (BM) 70.6 ± 5.0 kg. To be eligible for the study participants had to be free from injury and medication that affected the ability to exercise, and free from medication or medical conditions that influenced body fluid balance. Prior to inclusion, comprehensive written and verbal explanation of the study was provided to participants and parents, written parental informed consent and child assent was received, and a medical questionnaire was completed. The study received ethical approval from the Abertay University School of Social and Health Sciences Research Ethics Committee.

Experimental design

On three separate occasions, a sample of the first urine output upon waking was collected from each participant. Participants were instructed to refrain from strenuous exercise, other than the normal prescribed training sessions, for at least 24 h before providing the sample, but were otherwise permitted to go about their normal activity and dietary routine. Participants brought the samples into the laboratory the same morning they were deposited, whereupon they were analysed for USG using a clinical refractometer (model A300, ATAGO Co., Tokyo, Japan) calibrated according to manufacturer guidelines. These samples provided baseline hydration data for each participant that served as a comparison for the pre- and post-training hydration data (Shirreffs and Maughan, 1998). For all analyses, USG values <1.020 were considered indicative of euhydration, and values ≥ 1.020 indicative of hypohydration (Oppliger and Bartok, 2002).

Training sessions

Data collection took place over three consecutive training sessions near the end of the competitive season (April/May 2012), beginning with the first training session of the week. Sessions one and two were separated by 72 hours, and sessions two and three by 24 hours. The goal was to quantify hydration status during normal training sessions; therefore, every effort was made to prevent interference in the normal training-day practices and lo-

gistical decisions of the participants and coaching staff. To assist this aim, the researchers did not introduce any measurements or procedures that were not normally undertaken by the coaches and players, did not provide access to any additional fluid above that normally provided, and maintained a minimal physical presence during the training sessions. Training sessions took place on an outdoor grass football pitch (sessions 1 and 2) and an indoor Astroturf surface (session 3), commencing at ~10:30 am and lasting for ~75 min. The sessions consisted of a warm-up, specific ball drills, and simulated game drills. All participants wore standard training clothing (t-shirt/long-sleeved shirt, bib, shorts, socks, boots), and did not change their clothing during the session. Ambient temperature and humidity during the training sessions was recorded using a digital hygrothermometer (Tako Astatic Technology, Malaysia).

On arrival at the training ground, participants were instructed to empty their bladder as completely as possible and defecate if required. A urine sample was taken for the estimation of USG. Body mass was then measured using an electronic scale accurate to 0.1 kg (SECA 770, Avery Weight-Tronix) with participants wearing only cotton briefs. Urine sampling and BM measurement occurred within ~30 min before the start of training, and urine was analysed within ~30 min of the sample being provided. Each participant then dressed for training, including fitting a heart rate (HR) monitor chest strap (Polar Team² Pro, Polar, New York, USA) which recorded HR at 1 sec intervals for the duration of the session. Urine output and fluid ingestion were monitored during this 30 min pre-training period.

During training, participants were instructed to collect any passed urine in labelled plastic containers so that this could be incorporated into the calculation of BM loss and SR. Only one participant urinated during training (session 3). Participants could consume water *ad libitum* until the end of the session from sealed, individually numbered 500 ml bottles (three per participant). Participants were only permitted to consume water from bottles carrying their personal identification number, and were informed not to spit out any of the fluid or use any to rinse their faces. The bottles were located at the side of the training pitch, and participants had the opportunity to consume fluid during the periods of training when instructions were being provided by the coach, and were also prompted on various unscheduled occasions to consume fluid by the coach. Immediately on completion of training, participants were instructed to stop drinking and the bottles were removed from the training area. Each bottle was weighed to determine the amount of fluid consumed by each participant. Following training, participants were asked to empty their bladder as completely as possible into the container provided. Post-training urine volume and USG were then measured within 30 min from provision of the sample. Participants then towelled dry and had their BM measured using the same procedure as pre-training. This occurred within ~15 min of the end of training. Participants were not allowed to eat or drink anything from the end of the training session until post-training BM had been measured.

Body mass loss and sweat rate

Body mass loss was calculated from the difference between pre- and post-exercise BM, corrected for fluid intake and urine output. Sweat rate ($L \cdot h^{-1}$) was calculated using the equation: (Pre-exercise BM (kg) - post-exercise BM (kg)) + (fluid ingested (L) - urine output (L))/protocol duration (min) \times 60 (Edwards et al., 2007). This calculation does not account for BM loss due to fuel oxidation and respiratory fluid loss. The applied nature of this protocol meant it was not possible to accurately correct for the influence of fuel oxidation or respiratory fluid loss on BM loss. However, these factors would have been a negligible component of total mass loss (Maughan et al., 2004).

Statistical analyses

Data analysis was undertaken using Statistical Package for the Social Sciences (SPSS; version 20, Chicago, USA). The Shapiro-Wilk test assessed data distribution, as it is sensitive to smaller data sets (Field, 2005). A required sample size of 12 for a statistical power of 0.80 was calculated using G*Power (v. 3.1.7, Universität Kiel, Germany) based on a moderate effect size (Cohen's $f = 0.25$) for the change in first morning USG (Armstrong et al., 2010). Paired t-tests compared pre- and post-exercise BM in each session. Fluid intake, SR, and HR during training, BM loss, urine output, first morning hydration status, and ambient temperature and humidity between sessions, were analysed using one-way ANOVA with repeated measures. Urine specific gravity was analysed using a 3 \times 3 ANOVA (session \times time) with repeated measures. For all ANOVA analyses, the Greenhouse-Geisser adjustment to the degrees of freedom was applied if sphericity was violated. Cohen's d effect sizes were calculated and defined as small ($d \leq 0.2$), medium ($d > 0.2, < 0.8$), and large ($d \geq 0.8$; Cohen, 1992). Unless specified, data were mean \pm standard deviation (SD) and statistical significance was set at $p < 0.05$.

Results

Mean ambient temperature was 12.9 ± 0.7 , 8.9 ± 0.3 , and $17.2 \pm 0.1^\circ C$ for session 1, 2, and 3, respectively ($F_{1,15.5} = 417.1$, $p < 0.05$). Mean ambient temperature in each session differed significantly from all other sessions ($p < 0.05$, $d = 6.1$, 14.0 , and 14.0 for session 1 and 2, 2 and 3, and 1 and 3, respectively). Mean relative humidity was 50.3 ± 2.3 , 76.8 ± 1.3 , and $50.5 \pm 0.5\%$ for session 1, 2, and 3, respectively ($F_{2,10} = 500.5$, $p < 0.05$). Mean relative humidity was significantly greater in session 2 than session 1 and 3 ($p < 0.05$, $d = 14.0$). There was no significant difference between session 1 and 3 ($p = 1.0$, $d = 0$).

Mean training intensity, expressed as percentage of maximum HR (HR_{max}) derived from a field-based intermittent endurance test conducted approximately 2 weeks prior to the study, was 66.9 ± 6.6 , 66.3 ± 5.1 , and $59.4 \pm 5.4\%$ for sessions 1-3, respectively ($F_{2,12} = 13.7$, $p < 0.05$). Mean HR in session 1 was significantly greater than session 3 ($p < 0.05$, $d = 1.86$) and in session 2 was significantly greater than session 3 ($p < 0.05$, $d = 1.81$).

There was no significant difference between sessions 1 and 2 ($p = 1.0$, $d = 0$).

Body mass changes, SR, fluid intake, urine output, and percentage of sweat losses replaced for each session is in Table 1. Post-exercise BM was significantly lower than pre-exercise BM in all three sessions ($p < 0.05$), with BM loss significantly greater in session 1 compared to sessions 2 and 3 ($F_{2,26} = 6.5$, $p < 0.05$). Mean SR was significantly influenced by training session ($F_{2,26} = 10.2$, $p < 0.05$), being significantly greater in session 1 compared to session 2 and 3 ($p < 0.05$, $d = 1.70$ and 1.61 , respectively). Across the three training sessions, participants consumed sufficient fluid to replace $71.3 \pm 64.1\%$ of sweat losses (range 0 – 363.6%).

Table 1. Pre- and post-exercise body mass (BM), BM loss, fluid intake and urine output for the three training sessions. Data ($n = 14$) are means (\pm SD)/[min-max].

	Session 1	Session 2	Session 3
Pre-ex BM (kg)	70.6 (5.0) [62.7-80.6]	71.0 (5.3) [62.3-80.8]	71.0 (5.0) [63.4-79.9]
Post-ex BM (kg)	70.3 (4.9)* [62.5-80.1]	70.8 (5.2)* [62.4-80.6]	70.7 (4.9)* [63.2-79.9]
BM loss (kg)	.69 (.22) [.39-1.16]	.42 (.25)† [.02-.92]	.38 (.30)† [.06-1.13]
BM loss (%)	.97 (.29) [.57-1.54]	.58 (.35)† [.03-1.31]	.52 (.39)† [.08-1.50]
Sweat loss replaced (%)	62.3 (30.7) [15.8-127.5]	85.7 (65.2) [23.8-254.4]	65.8 (96.5) [0-363.6]
Sweat rate ($L \cdot h^{-1}$)	.55 (.18) [.31-.93]	.27 (.16)† [.01-.59]	.29 (.23) † [.04-.88]
Fluid Intake (ml) ‡	425 (185) [119-777]	355 (161) [38-503]	247 (157) [0-511]
Urine Output (ml)	123 (92) [45-312]	108 (66) [40-263]	128 (124) [42-447]

* Significantly different from pre-ex BM ($p < 0.05$); † Significantly different from session 1 ($p < 0.05$); ‡ A significant main effect of session was reported ($F_{2,26} = 5.0$, $p < 0.05$), but post-hoc tests could not determine the location of the significance.

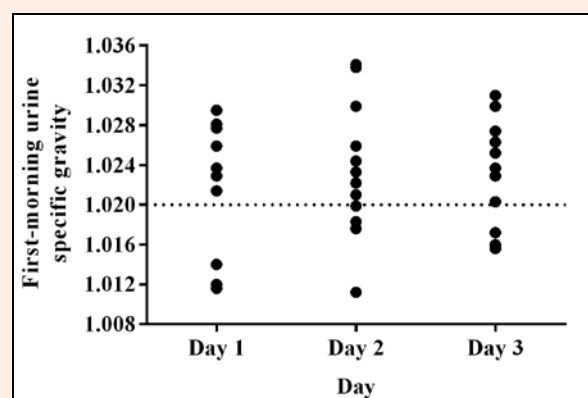


Figure 1. Urine specific gravity for three first-morning urine samples collected between 7-8am ($n = 13$). Dotted line indicates the cut off value for hypohydration (> 1.020).

Mean USG for the three first morning urine samples is in Figure 1. When individual participants' data was considered, 77% of participants were hypohydrated upon waking on days 1 and 3, and 62% on day 2.

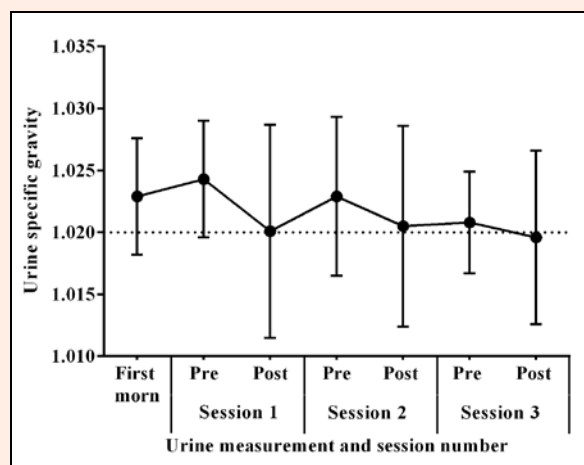


Figure 2. Mean urine specific gravity at first morning and pre- and post-training for all three training sessions ($n = 13$ for first morning sample and $n = 14$ for all other samples). Data are mean \pm SD.

Mean USG at first morning, and before and after each training session, is in Figure 2. There were no significant differences in USG between the three first morning samples ($F_{1,12} = 0.001$, $p = 0.97$). Therefore, the three data sets were grouped for analysis with the pre- and post-training data. There was no significant difference between mean first morning USG and pre-training USG for any session ($F_{3,36} = 2.2$, $p = 0.11$). There was no significant influence of training session ($F_{1,4,18,6} = 1.1$, $p = 0.34$), time ($F_{1,13} = 2.3$, $p = 0.16$), or interaction ($F_{2,26} = 2.2$, $p = 0.14$). Changes in BM and USG pre- to post-training showed no significant relationship across the three training sessions ($p = 0.33$, Figure 3).

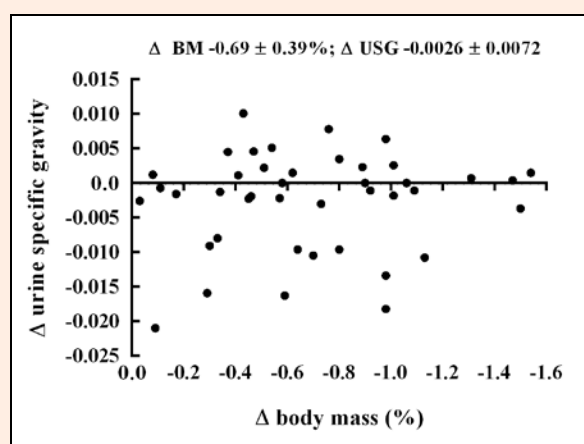


Figure 3. Individual and mean \pm SD values of change in body mass and change in urine specific gravity pre- to post-training for all three sessions ($n = 42$).

Discussion

The main findings of this study are: 1) The majority of elite young European soccer players appear hypohydrated at first morning, when a USG threshold of 1.020 is applied; 2) Body mass loss, fluid intake, and USG measures

showed large inter-individual variation; 3) Elite young European soccer players replace approximately 71% of their sweat losses during training; 4) When training in cool conditions, replacing 71% of sweat losses results in minimal hypohydration ($<1\%$ BM).

Previous research investigating the hydration status and fluid balance of adolescent team games players did not quantify first morning hydration status (Da Silva et al., 2012; Silva et al., 2011). Therefore, comparing the current study to other work is difficult. However, what is important is that a large number of participants were hypohydrated upon waking and did not significantly improve their hydration status prior to training several hours later. As a result, many participants were starting each training session hypohydrated. This practice is in conflict with current fluid intake guidelines that recommend consumption of sufficient fluid in order to begin training euhydrated (Sawka et al., 2007).

Interestingly, individual training sessions did not cause a further deterioration of hydration status, nor was there a cumulative effect of the sessions. Therefore, in contrast to other research (Godek et al., 2005; Silva et al., 2011), the participants in this study were able to maintain a stable hydration status during three consecutive training sessions. However, the studies of Godek et al. (2005) and Silva et al. (2011) were undertaken in markedly different environmental conditions to the current work. What is again important to highlight is that although participants in the current study were generally able to maintain their hydration status across the training sessions, a large proportion of participants were maintaining a hypohydrated state.

This study used a threshold USG of >1.020 as indicative of hypohydration. This USG threshold has much support in the hydration literature (Bartok et al., 2004). However, it has been shown that the USG threshold to detect hypohydration may be higher (>1.025) in athletes with larger relative muscle mass (Cheuvront et al., 2010; Hamouti et al., 2010). Therefore, it is possible that the USG threshold used in the current study may have classified some athletes as hypohydrated when in fact they were euhydrated. However, the absence of body composition data for the athletes in this study means that a judgement on whether to use the higher USG threshold based on the Hamouti et al. (2010) data could not be made. Therefore, it was decided to use the well-accepted USG threshold of >1.020 to quantify hydration status in the current study.

Participants consumed sufficient fluid to replace approximately 71% of sweat lost during training. This level of fluid intake resulted in a statistically significant BM reduction in each training session. The extent of fluid replacement in the current study is larger than that reported by Da Silva et al. (2011) during competition in elite young heat-acclimatised players performing in a warm environment. This larger fluid intake may be related to the nature of the exercise; Da Silva et al. (2011) conducted their study in competition, whereas the current study examined training sessions, which may have provided more opportunities for fluid consumption (Clarke et al., 2008).

There was no significant relationship between changes in BM and changes in USG pre- to post-training, in line with some previous findings (Cheuvront et al., 2010). However, both BM and USG showed a small mean reduction from pre- to post-training across the three sessions. There was a large inter-individual variation in fluid intake, BM loss, and USG changes, again in line with other findings (Bartok et al., 2004; Cheuvront et al., 2010). Participants in this study were not required to complete a standardised pre-exercise fluid intake strategy, and fluid was consumed in an unstructured fashion during training. Drinking behaviour is known to confound urine hydration interpretation (Cheuvront et al., 2010). Specifically, USG can be influenced by the timing of fluid intake, as extracellular fluid (ECF) osmolality is regulated in preference to ECF volume (Popowski et al., 2001). Therefore, acute fluid intake in the latter stages of training could have promoted urine formation in order to maintain ECF osmolality, which would have resulted in more dilute urine and could explain the slight mean reduction in USG pre- to post-training (Popowski et al., 2001). In this situation, USG measures would not necessarily provide an accurate representation of hydration status.

The notable inter-participant variation in SR, BM loss, and fluid intake observed in the current study agrees with previous work in young players (Silva et al., 2011) and adults (Maughan et al., 2005; Shirreffs et al., 2005) during training and competition. It is likely that variations in participant's body composition, fitness levels, exercise intensity, and biological maturation status (Rowland, 2008; Sawka et al., 2007) played a role in this inter-participant variation. The inter-participant variation in BM loss must be taken into account when prescribing fluid intake regimes, as it suggests that generic fluid intake guidelines for an entire team may be inappropriate and alterations to fluid intake practices should be considered on an individual basis (Silva et al., 2011), in agreement with current fluid intake guidelines (Sawka et al., 2007).

Prescription of fluid intake regimes should also consider the magnitude of hypohydration that occurs. In the current study, BM loss incurred during training was statistically significant, but the actual extent of hypohydration was small (<1% BM), and lower than that reported for adult soccer players training in a cool environment (Shirreffs et al., 2005). Of course, differences in training intensity and duration could account for differences in fluid loss between studies. However, the data from this study indicates that replacing ~71% of the fluid lost during training in a cool environment results in only nominal hypohydration in elite European youth soccer players.

Current exercise and fluid replacement guidelines recommend that individuals should develop customised fluid replacement regimes that prevent excessive ($\geq 2\%$ BM) dehydration (Sawka et al., 2007). In the current study, no participant recorded a training-induced level of dehydration $\geq 2\%$ BM with *ad libitum* water intake. As a result, it appears that *ad libitum* water ingestion by young elite European soccer players training in a cool environment prevents excessive dehydration as defined by current fluid intake and hydration guidelines (Sawka et al.,

2007). Therefore, current fluid intake guidelines seem to be applicable to this form of soccer training in this population.

Practical applications

This study presents the first published data investigating the fluid intake and hydration status of elite young European soccer players during habitual training in a cool environment. While the data cannot be confidently extrapolated beyond the participants used, the finding that the participants were waking, beginning and ending training in a hypohydrated state should act as a stimulus for other soccer clubs and academies to closely monitor the hydration practices of their young players. This is important considering the ongoing debate as to the influence of dehydration on soccer performance (Edwards and Noakes, 2009). A second practical application is that ingestion of fluid equal to ~71% of sweat losses only resulted in nominal hypohydration following training. It therefore appears that existing recommendations for fluid intake during exercise, namely the use of individualised fluid intake regimes to prevent excessive hypohydration ($\geq 2\%$ BM), are applicable, and should be applied, to young elite European soccer players training in a cool environment. Finally, as the majority of athletes in the current study woke and began each training session hypohydrated, monitoring of hydration status in elite young players should include first morning hydration assessment. This will enable the development of strategies for improving pre-training hydration status, in line with current recommendations (Sawka et al., 2007).

Conclusion

Three days of habitual training did not significantly influence the fluid balance and hydration status of elite young European soccer players. However, a large proportion of players were hypohydrated upon waking, prior to and after each training session. A large inter-individual variation in SR, fluid intake, BM loss, and USG values in response to training was observed. However, *ad libitum* ingestion of sufficient fluid to offset ~71% of sweat losses during training resulted in nominal hypohydration. Therefore, current fluid intake recommendations appear valid for elite young European soccer players training in a cool environment. However, the high incidence of players beginning training hypohydrated suggests that prehydration strategies may be of benefit.

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Key points

- The paper demonstrates a notable inter-participant variation in first morning, pre- and post-training hydration status and fluid balance of elite young European soccer players.
- On average, elite young European soccer players are hypohydrated upon waking and remain hypohydrated before and after training.
- Elite young European soccer players display varied fluid intake volumes during training, but on average do not consume sufficient fluid to offset fluid losses.
- Consecutive training sessions do not significantly impair hydration status, suggesting that elite young European soccer players consume sufficient fluid between training to maintain a stable hydration status and prevent excessive ($\geq 2\%$ body mass) dehydration
- Current fluid intake guidelines appear applicable to this population when training in a cool environment

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